TRANSLATION

World Intellectual Property Organization
International Office
INTERNATIONAL APPLICATION PUBLISHED UNDER
THE PATENT COOPERATION TREATY (PCT)

(51) International patent classification[6]: G01M 1/30, 1/38	A1	(11) International publication number: **WO 00/11445** (43) International publication date: March 2, 2000

(21) International application no.: PCT/EP98/07088	(81) Determining countries: HU, JP, KR, PL, US, European Patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).
(22) International filing date: November 6, 1998	Published *With an international search report*
(30) Priority data: 198 37 680.4 Aug. 19, 1998 DE	
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(54) Title: METHOD FOR IMPROVING CONCENTRICITY IN AUTOMOBILE TIRES

(57) **Abstract**

The invention relates to a method for improving concentricity in an automobile tire (1), wherein the bead (2) of the tire undergoes further processing after vulcanization to improve concentricity. In order to enhance the possibilities offered by such additional processing, the invention provides that the bead (2) be deformed in a plastic manner at least sectionwise during further processing. Preferably, no material is used during said operation. Plastic deformation is effected by the combined effect of very high pressures and high temperature. This makes it possible not only to bring the bead core closer to the rim seating surface, as is the case when the known method of grinding down the bead is used, but also to further separate the bead core from the rim seating surface without using additional components.

Specification:

Method for Improving Concentricity in Automobile Tires

The invention pertains to a process for improving the concentricity of a vehicle tire, wherein its bead is subjected to an aftertreatment after vulcanization that improves the concentricity.

It is known from DE-OS 2,715,111 that to reduce the tire imbalance the finished, vulcanized tire can be subjected to an aftertreatment such that additional rubber is applied to or removed from the axially interior sides of the tire bead.

It is known from EP 0,405,297 that through a removably fastened annular disk of adapted thickness over the circumference in a similar manner as in the above-mentioned citation in opposition, the bead can be displaced locally in such a way that in the tread area it produces a more uniform radial force at a given degree of tire camber.

It is known from DE 4,339,775 A1 that at the points, thus phase layers, where the tire produces excessive radial force or shows a somewhat too large tread radius, some rubber can

be removed from the bead surface pointing radially inward, preferably ground off. This state of the art seems to us to be the closest [to the present invention].

Correction of tire imbalances is also considered in US Patents 3,550,442; 3,719,813; 3,862,570; 4,016,020, and 4,414,843, as well as the Japanese application 61-195,809.

The subsequent rubber application, as is already known from the aforementioned DE-OS 2,715,111, presents difficulties in practice, since as a rule the tire blank is coated with a release agent before vulcanization. At the points where it is subsequently desired to remove rubber and vulcanize it on firmly, this release agent must be reliably removed and the joint surface roughened; both of these are several-fold more expensive than removing rubber from any place whatsoever.

One drawback of the process according to DE 4,339,775 A1 is that this type of error compensation is practically irreversible, since—as explained above—the subsequent (re)application of rubber is very tedious; from this it follows that as a rule the first correction is already the last possible. Therefore before irreversible removal a very high certainty must prevail about how much is to be removed at what point. According to experience to date, good results are achieved in this way if and only if each treated tire was previously measured individually, even if the tires of one manufacturing batch, in addition to the random errors, have a common systematic error.

An additional drawback of the process mentioned is the fact that the rubber removal leads to contamination of the workplace.

To be sure, the previously cited EP 0,405,297 avoids these two drawbacks, but is unpleasant for all tire mounting companies, thus the automobile manufacturers and the tire retailers, in that two additional components per wheel must be handled.

The goal of the present invention is to avoid all three drawbacks of the aforementioned solutions in a simple way.

First of all the inventors recognized that the bead should be retained as the intervention site since only in this way, thus by avoiding the tread surface as the intervention site, will the performance and lifetime of the tire be unaffected by the corrective operation. They also recognized that the task that they faced was insoluble within the customary conceptual model, since if no additional component is to be present, removal is to be avoided because of irreversibility, and application is decisively too expensive, at first nothing else seems possible.

Into this hopeless appearing field of competing goals, the inventors burst with their idea of achieving the task in that the bead should be plastically reformed, at least in certain areas, during the aftertreatment. Behind this is the surprising observation that many rubber mixtures can be more or less thermoplastically deformed at sufficiently high pressure, sufficiently high temperature, and sufficiently high contact times. This is surprising, since vulcanized rubbers are considered to be elastomers, see for example DIN 7724. Here it is stated: "Elastomers—also known as vulcanizates or rubber in ordinary speech—have ... a glass transition temperature T_g of less than 0°C and no flow region above the temperature range of use up to their decomposition." In the report on the technical meeting, "Elastomer strips in flat roof construction" held on March 24, 1981 in Frankfurt/Main, printed in the journal *Kautschuk + Gummi ·Plastics*, vol. 34, no. 11/81, pages 927 to 937, the following is stated on

page 931, right hand column, beginning with line 4:

"... Elastomers are rubber-elastic polymer materials that are no longer thermoplastic moldable, thus have no flow range. This is now achieved by the vulcanization process, in which the macromolecules are cross-linked with one another in such a way over chemical bonds that they no longer slide with respect to one another, i.e., cannot flow."

The quasi thermoplastic flow produced according to the present invention takes place distinctly more slowly than in the case of the known thermoplastics and known thermoplastic elastomers. In quasi-thermoplastic flow, a purely physical gliding past of chain molecules past one another does not seem to be involved, but rather a breakdown of highly stressed sulfur bridges and reconstruction of less highly stressed sulfur bridges, thus sulfur bridge rearrangement:

If the most highly stressed and thus highest energy sulfur bridge is replaced by a lower stress one, all other sulfur bridges are slightly more highly stressed. After this increased load, the formerly second most highly stressed sulfur bridge gives way and is replaced under energy release by a less high-stress sulfur bridge and so forth. The jumping of the sulfur bond, indicated but not yet finally proven, from one anchor atom of the polymer and/or filler atom to another anchor atom thus would also be a mechanically induced chemical process.

The sequence and result of this chemical process is influenced not only by the mechanical stress but also by the process temperature and the time available for the process. Increasing the process temperature and/or the process time makes it possible to achieve the same permanent dimensional change by reforming with a lower mechanical stress; the decrease in the required mechanical stress through a temperature elevation and/or time

increase, however, can be represented over a very small temperature range as a linear function.

Even if the same permanent dimensional change is achieved with reduced mechanical stress and correspondingly elevated temperature and/or process time, nevertheless the result does not agree, since the hardness of the final product is also essential; an increase in the process temperature and/or the process duration, in addition to the previously mentioned—and welcomed—displacement of the sulfur bridges from former to newly found anchor atoms also leads to more frequent fracture of the sulfur bridges, which have become less stable not only on their anchor atoms but also internally, so that after treatment, more and shorter sulfur bridges are present, bringing about greater hardness of the final product.

Therefore—for maintaining adequate softness of the treated beads—an excessively high processing temperature is to be avoided, just as is an excessively high processing time. The latter is also to be avoided for the economic reasons that the interest on the capital employed must not be so greatly reduced by excessively long manufacturing times. A favorable adjustment of the parameters of stress, temperature, and time is the subject of Claims 5 and 8.

It has proven advantageous for the performance of the process if the rubber mixture contains at least 10 times as much sulfur as is actually utilized for sulfur bridge formation in view of the selected vulcanization data such as vulcanization time, vulcanization temperature, accelerator selection and dose, as well as retardant selection and dose in the vulcanizate; this may be explained by the fact that without an adequate excess of sulfur in the mixture, the replacement of the most highly stressed bridges by a less stressed sulfur bridge of similar

length becomes too unlikely, since the migration pathways of some of the sulfur atoms required for this become too long; in the case of an inadequate sulfur oversupply, as a replacement for an overstressed, long sulfur bridge, two shorter sulfur bridges form, which recruit sulfur atoms from a smaller intake area and therefore require only shorter migration pathways. An inadequate sulfur excess thus acts similar to an elevated process temperature, thus is highly hardening. A particularly good quasi-thermoplastic behavior under high pressure effect is achieved by bead rubber mixtures when they contain 30 to 90 times the quantity of sulfur that actually formed sulfur bridges in the vulcanizate.

During use of the brakes of a wheel—usually arranged immediately adjacent to the rim—the rim becomes considerably heated, which leads to an increase in diameter of the seating surface and thus to an increase in the compression. To sustain the minimum compression necessary to protect the tire from turning on the rim in the case of longitudinal force transfer and from separation in the case of low air pressure even after the rim has cooled again, the bead rubber must expand radially inward again in an elastic fashion after recooling of the rim.

To achieve this safety, only a rubber mixture can be used in the bead area the residual deformation of which is extremely small; therefore, bead mixtures were and are being "bred" to be highly elastic. For this reason the functioning of the suggested solution, where a permanent deformation is to be created, seemed unlikely.

The problem of the temperature-related change in diameter appears more sharply when the fluctuations of the outdoor temperature are considered as well, if a material with a different coefficient of elongation relative to the modulus of elasticity is used for the rims

than for the strength carriers of the bead core, thus especially the use of rims made of alloys with aluminum and/or magnesium. The coefficient of linear expansion for iron is known to be 1.2×10^{-5}, the modulus of elasticity 2.1×10^{5} N/mm^2, whereas the coefficient of expansion for aluminum is 2.2×10^{-5} and the modulus of elasticity 0.65×10^{5} N/mm^2. With increasing outdoor temperature and temperature uniformity of rim and tire bead therefore when an aluminum rim and a steel bead core are used, the pressure at the base of the tire becomes lower.

Thus summarizing the consideration of the diameter fluctuations it was already important (and continues to be in the case of the invention) that the residual deformation that may be caused by the operating conditions is extremely small. The stresses or surface pressures used in the reforming according to the invention, however, are significantly greater than those occurring under the anticipated operating conditions. And under this higher mechanical stress, the sulfur-vulcanized rubber—as discovered by the inventors and shown in the preceding paragraphs—behaves quite differently. This different active ingredient behavior used for the process in accordance with the invention was not to be expected from an extrapolation of the previously known force-deformation behavior.

The plasticity achieved through the use of substantially higher mechanical stresses is not reversible without residue in contrast to the behavior of the thermoplastics and the thermoplastic elastomers; even a single reversion of the "quasi-thermoplastic" deformation previously achieved in accordance with the invention through a second, oppositely directed quasi-thermoplastic deformation leaves behind a small degree of hardening at the treatment site. Passing through such a plastic deformation cycle multiple times finally leads to brittle

fracture; on this basis the rubber in the load range taught is more similar to the plasticity behavior of the metals and not to that of thermoplastic polymers, here briefly designated as thermoplastics.

A particularly interesting point in the solution in accordance with the invention lies in the fact that no material needs to be removed from the bead, or indeed anywhere from the tire, during the aftertreatment, and preferably this is also not done according to Claim 2.

According to Claim 9, first in a manner known in and of itself, the place is (are) removed, at which a radial quantity of the tire exceeds a threshold value. As the radial quantity (as intended within the framework of this entire application) preferably the radial force of the tire is used, which is recorded in advance in one or more axially distributed tracks—if one, approximately in the center—as a function of the angle of rotation. However, it is also possible to use the radius of the tire itself as the radial value; fluctuations in the cord length from bead to bead are thus indicated just as well, but rigidity fluctuations, such as those that occur for example at overlap sites, are less accurately recorded.

After this, at least at the point where this radial quantity of the tire exceeds the threshold value and is greatest, but preferably at all locations where the radial quantity of a threshold value is decisively too large, the radial quantity of the tire is reduced, specifically through the fact that the bead core at this location is brought closer to the essentially axially extending bead seating surface.

The local approximation of the bead core to the, for example, axial bead seating surface advantageously takes place in that according to Claim 3 the regional reforming of the bead takes place through local action of a force component, pressing from radially inward to

radially outward, against the essentially axially extending bead seating surface of the tire and through the action of heat. Thus it is a matter of the joint action of force and heat.

At least one of the two components acting together, force and heat, must be locally differentiated in such a way that it only includes the point(s) to be reformed; according to Claim 3 the force is locally differentiated, which is easier to achieve according to studies to date than the locally differentiated heat application according to Claim 4, although this is also possible. In addition, it is naturally also possible to apply both force and heat locally differentially, thus not uniformly over the entire bead circumference.

As was already the case according to Claim 9, then also according to Claim 10 at least in a manner known in and of itself the point(s) is(are) determined at which a radial quantity of the tire crosses a threshold value, but in this case drops below it. Then at least at the point where this radial quantity of the tire drops below the threshold value and is smallest, but preferably at all points where the radial quantity is too small, dropping below a threshold value, the radial quantity of the tire is increased.

Specifically, this radial quantity is increased in that the bead core there is brought farther away from the essentially axially extending bead seating surface.

The local distance increase between the bead core and approximately axial bead seating surface advantageously takes place in that according to Claim 6 the regional reforming of the bead takes place by local action of a force component that compresses an area of the bead to be treated against its essentially radially extending delimitation surface and through the influence of heat. Therefore here as well it is a matter of the interaction of force and heat. And as was already explained with the pair of Claims 3 and 4, the local distance

enlargement is also possible with local differentiation of the heat rather than the force—which is the object of Claim 7—or in addition to this.

Thus for the first time an increase in distance has become possible without the need for additional individual parts and/or joining operations such as adhesion, whereas distance reductions were possible up to now without individual additional parts and/or joining operations, but only by grinding, thus under loss of material, which disadvantageously influences the balance of the tire and is irreversible.

The distance enlargement according to Claim 6 and/or 7, contrary to the distance reduction—both relative to an inventive process according to Claim 3 and/or 4 as well as relative to a conventional process through grinding—makes possible the compensation of larger errors, since movable or removable volumes are attacked from two sides, namely the two axial sides, and not only from one, namely the radially interior side.

Claim 5 teaches suitable measures for achieving a distance reduction according to Claims 3 and/or 4, and Claim 8 teaches suitable measures for achieving a distance increase according to Claims 6 and/or 7. Correspondingly the radially outward pressing or axially compressing force component amounts to between 50 and 150 N per mm circumferential length of the sector of the essentially axially or radially extending bead surface or bead surfaces in which the plastic reforming of the bead is to take place, and the heat at least in the area of the bead amounts to between 100°C and 230°C, preferably between 160°C and 180°C, at a duration of the joint action of force and heat between 10 minutes and 45 minutes.

A variant of the locally different heat application according to Claim 4 and/or 7 is locally differentiated cooling during performance of the improvement process in accordance

with the invention closely or immediately after vulcanization, thus at a time when the tire is still hot. Thus in this variant no further heat whatsoever is introduced into the tire by means of the improvement device, but instead cooling is performed in the areas in which the bead is not to be reformed, whereas the areas that are to be reformed are not cooled, or at least are cooled to a lesser extent. In contrast it may be reasonable to wrap the areas of the bead to be reformed with heat insulating means.

The utilization of the residual heat of vulcanization in the tire is naturally also possible in the case of non-local differentiation of the heat, as Claim 3 and/or 6 teaches in the case of local differentiation of the reforming force; for this reason it may be advisable to envelop the entire bead surface in a thermally insulating manner.

The concentricity improvement process in accordance with the invention is less suitable for correcting short-wave concentricity disturbances, but is highly suitable for correcting long-wave disturbances. Correction appears possible to the sixth harmonic, wherein a local force differentiation seems to permit shorter wave corrections than a local heat differentiation. Under consideration of the previous economic boundary conditions, the process in accordance with the invention is advantageously used only to correct the first, second, and third harmonics of the periodic function that represents the radial quantity as a function of the angle of rotation. The correction of the first harmonic is especially easy.

Corresponding to this recognition it is advisable in accordance with Claims 11 and 12 first to determine a radial quantity of the tire—preferably its radial force—over at least one full wheel rotation as a function of the wheel rotation angle and then subject it to such an

extensive Fourier analysis that at least the first—preferably the first, second, and third—harmonic of this function is determined.

After this data detection it is necessary to decide whether the maxima of the filtered out harmonics are to be reduced in size or the minima increased, or whether both maximum reduction and minimum increase are to be carried out according to Claim 13, which is especially to be recommended for the treatment of the particularly important first harmonic. A mixed procedure is also possible, for example of the type such that a minimum increase and a maximum reduction is performed in the case of the first harmonic, an increase in both minima alone in the case of the second harmonic, and a reduction of the three maxima in the case of the third harmonic.

For a maximum reduction according to Claim 11, in the area of the maximum or minimum of the harmonic in question—this must not be a maximum of the function of the radial quantity itself—the radial quantity of the tire is reduced there, and specifically in such a manner that the bead core there is brought according to at least one of the Claims 3 and 4 closer to the bead seating surface extending essentially axially.

For a minimum enlargement according to Claim 12, there, thus in the area of the minimum or minima of the harmonics in question—this must not be a minimum of the function of the radial quantity itself—the radial quantity of the tire is increased, and specifically in that the bead core there is brought further away from the essentially axially extending bead seating surface according to at least one of the Claims 6 and 7.

The average wheel load of a passenger car of the lower medium size class, for example VW Golf, Opel Astra, Ford Escort, or Toyota Corolla, is 2,750 N. In the current

status of tire manufacturing technology, on a freshly vulcanized tire the typical amplitude of the superimposed first harmonic, depending on the price that the purchaser is prepared to pay and thus the degree of care that the tire manufacturer can apply, is between 40 and 125 N, thus between about 1.5% and 4.5% of the wheel load.

Tires are frequently demanded with an amplitude of the first harmonic less than or equal to 80 N. Assuming that a tire is available, the amplitude of the first harmonic of which amounts to 85 N, the radial force change thus need not amount to 85 N, but only 5 N;

But once the tires are studied and handled, it is advisable also at the same time to strive for a larger radial change in force, preferably of 20% to 60%—particularly preferably about 40%—of the amplitude to be reduced, in this case by about 35 N. In brief, the height and orientation (and naturally also the phase length) of the desired advantageous radial force change results from a comparison of the actual radial force fluctuation with the maximum tolerated radial force fluctuation.

Beginning from the data obtained in this way and the dimensional statements of Claims 5 to 8, Claim 14 teaches the dimensioning of the correct contact time t of transforming force and heat according to the following formula:

$$t = c \frac{\partial R}{(T-T_O)^2}$$

Here, δR_f is the desired radial force change established according to the above-mentioned viewpoints, T is the intended reforming temperature, c is a constant that depends on the rubber mixture, and T_0 is the glass transition temperature of the rubber mixture used in the bead region.

For the rubber mixtures that are customary in the tire bead region, the constant c is between 1.0 and 2.8 x 10^{-7} mm^2/K^2sec, for most automobile tires between 1.6 and 1.8 x 10^{-7} mm^2/K^2sec. The pressure and heat treatment of the tire bead performed according to such a calculation leads to surprisingly low and reproducible concentricity errors.

The inventors were not satisfied with the fact that most radial fluctuations appear to be randomly distributed within available tire series. They were able to show that in making all tire blanks in a batch in such a way that the required bonding joints are arranged in respectively equal phase position, most of the concentricity deviations are presented as systematic errors. For this reason, and because of the aforementioned good reproducibility, they suggest in Claim 15, based on Claim 14,

a) that in the finishing of all tire blanks of a batch, the required joining sites be arranged in respectively the same phase position and

b) that all tire blanks of this batch be placed in a similar—preferably the same—vulcanization mold in a determined phase position and vulcanized,

c) that after this a representative population of n tires—wherein n is preferably equal to 8—is removed from this batch,

d) and all tires of this batch are cooled—preferably below 75°C—

e) after which each tire of this group is pulled onto a measurement rim and for each tire of this group a radial quantity [R_μ]—preferably the radial force—is measured over the angle of rotation (phi), wherein μ is to run from 1 to n,

f) after which these individually determined function courses of the radial quantity $R_\mu = f_\mu$ (phi) are averaged in a phase-correct, linear way to form a mean radial quantity $R_m = f_m \text{ (phi)} = 1/n \times [R_1 + R_2 + \ldots + R_{(n-1)} + R_n]$,

g) after which, depending on the mean radial quantity R_m(phi) determined in this way, the plastic bead reforming—in the preferred case according to Claim 14—is determined and subsequently the plastic bead reforming determined in this way is performed on all n tires of this group,

h) that thereafter each tire in this group is cooled again—preferably below 75°C—once again drawn onto a measurement rim, and for each tire in this group once again the radial quantity [R] measured over the rotation angle (phi) and compared with predetermined tolerance fields, and

i) in the case of maintenance of predetermined tolerance fields, all remaining tires in this batch are treated in the same way to reform the bead (2) plastically in certain regions.

According to a preferred further development of this process, according to Claim 16 in the rare case of nonmaintenance of the predetermined tolerance field according to feature (h) of Claim 15, an additional representative group is removed from this batch,

— wherein the additional group mentioned contains no tires from the first batch,

— after which the additional group mentioned is treated corresponding to the features d) to h) of Claim 15,

— after which if the predetermined tolerance fields are met, all remaining tires in this batch are treated in the same way, plastically reforming the bead in a regional fashion.

The tires of the first experiment of the concentricity improvement are thus recognized as nonrepresentative and eliminated; they are advantageously handled individually or their quality labeling is discounted. Since according to the experimental experience to date the nonrepresentative nature of the initially randomly selected group is only very rarely manifested, the economic advantages of the collective tire treatment overcome the disadvantage of the second treatment or downgrading that may rarely be necessary.

The highest and most uniform tire quality is achieved when, according to Claim 17, a radial quantity—preferably the radial force—was measured not only in a single measurement track, which would then have to lie in the zenith region of the tire, but in two tracks, namely one to the right and one to the left of the tire center. In the case of deviations—whether according to quantity or according to phase position—of the fluctuation of the radial quantity mentioned, then both beads of the tire can be plastically reformed in a manner differently from one another, but preferably nevertheless simultaneously. Here, the words "differently reformed" not only mean that the amount of reforming on both beads can be different but also that the arc length range(s) in which the one bead is plastically reformed can differ from the arc length range(s) in which the other bead is plastically reformed. According to the experimental results today, quantity deviations can be achieved equally well by a temperature differentiation as by a corresponding reforming force differentiation; to be sure, a phase deviation is achievable both by temperature and by reforming force differentiation, but more readily by a reforming force differentiation.

Independently of the question of whether for the sake of simplicity both beads should be treated in the same way or for the sake of higher precision, differently from one another, there are two possibilities—also able to be combined with one another—of achieving plastic reforming at predetermined circumferential sites but not at others:

a) a bed to be treated is exposed over its entire circumference to a spreading tension, but only at the sites to be reformed achieves a temperature above the required reforming temperature

(key word: locality of temperature)

and/or

b) a bead to be treated achieves over its entire circumference a temperature above the required reforming temperature, but only at the sites to be reformed is subjected to such a high spreading tension that a plastic reforming begins

(key word: localization of the reforming force)

For temperature application, especially easy in case b), it is possible instead of a heater with separate heat supply to utilize the heat of vulcanization nevertheless present. For this purpose advantageously according to Claim 18 the tires in a batch—aside from the tires of the representative population(s)

— are slowed in their cooling by sufficiently short time intervals between removal from the vulcanization mold and performance of the at least regional plastic bead reforming and/or

— by thermal insulating means, usually surrounding the tire beads

— to such an extent that the tires, at least in the bead region on pulling onto the device that brings about bead reforming, without supply of heat energy into the tire bead, still have a temperature between 100°C and 230°C, preferably between 160°C and 180°C.

From such a procedure an energy balance of the manufacturing unchanged in comparison to the state of the art results. Because of the relatively high specific heat of rubber and metal and the low thermal conductivity of rubber, furthermore a particularly rapid process sequence takes place, since the low additional time expenditure for the application and removal of the heat protective cap opposes the always considerable heating time that would otherwise be imposed.

The localization of the heat supply is more difficult to achieve because of the thermal inertia of the heating devices than the localization of the force supply, and only one of the two must take place locally (but naturally, both may take place locally). The localization of the heat supply with regard to the phase position still takes place most easily if the heating apparatus is arranged on the device in a fixed-phase position and the required variability of the phase position is achieved by a phase-appropriate placement of the tire to be reformed on this device instead of tire application in any arbitrary phase position and phase adjustability of the heating device. Specifically, in the case of the last-mentioned design, considerable currents must be connected over variable current pathways, which can cause electric arcs that induce fumes in the vicinity of rubber.

This problem in achieving localization of the heat effect (thus a heat effect that does not act uniformly on the entire circumference, but rather a locally concentrated heat effect) does not exist if this localization is not achieved by an energy supply concentrated at one

location but rather by thermal insulation concentrated at this location and/or cooling concentrated at the complementary locations. The latter is the subject of Claim 19, according to which the localization of the influence of heat is achieved in that before applying the reforming force, the regions of the bead that are to remain essentially non-reformed are cooled, preferably to a temperature below 75°C.

The previous parts of the specification are based on the recognition that tire irregularities, no matter how they came about, can be reduced or even eliminated by a subsequently achieved plastic bead reforming. Here the word "systematically" means that at least in one measurement track, preferably in two measurement tracks, first the possible irregularities—preferably the radial force—are determined according to their quantity and phase position, and then a bead reforming is calculated from this according to the absolute quantity and the phase situation.

A statistical comparison of tires post-treated in this way with non-post-treated tires gave the surprising result that tires post-treated in this way do not, for example, show higher fluctuations of the material thickness between the bead core internal radius and the bead internal radius, but lower ones. At first a greater fluctuation over the circumference was expected, since a reforming is performed. This unexpected fact suggests that a considerable fraction—about one-third—of the tire irregularities to be compensated in accordance with the invention is accounted for by precisely straight fluctuations of the aforementioned material thickness, also known as "internal rubberization thickness." To this extent the aforementioned plastic bead reforming is thus not only a process that controls a symptom, but a process that intervenes in the chain of causation.

According to the aforementioned knowledge, on the statistical average the tire uniformity is improved even with an unintentional but uniform—and therefore homogenizing—plastic bead reforming. The word "uniform" here means the path of the deforming segments; the forces are not at all uniform: in the phase positions where more rubber is located below the bead core, in the case of uniform pathways more reforming force is applied than in the phase positions where less rubber is located below the bead core.

In analogy to the bead expanse that is uniform in terms of the path, a shrinkage of the lumen of the bead, likewise uniform according to path, likewise leads to a homogenization in the radial force recording. This is—likewise addressed in Claim 20—possible through an axial compression uniform in path under exercising of pressure on the essentially radially extending surfaces of the bead.

All of the further developments of the process in accordance with the invention mentioned, the plastic bead reforming after tire vulcanization, show that new devices are to be created for performing this. According to current knowledge these devices are suitable for nothing other than precisely the execution of the process mentioned.

Advantageously the first variant of the further development in accordance with the invention according to Claim 20 is carried out in that the tire bead is pressed axially onto a conical calibration rim according to Claim 21 at a bead temperature between 100°C and 230°C. In this way the material distribution in the core region, especially between the bead core inner circumference and the bead inner circumference, is made uniform.

The device according to Claim 21 can be modified in that the bead-expanding, conical drum is not round but is executed with an inconcentricity of first, second, or third order, which leads to a device according to Claim 22.

"Inconcentricity of the first order" means that the cross-sectional contour in each axial position of the cross-sectional plane, represented in polar coordinates, does not show a constant radius, but a fluctuating radius R according to a function $R = R_m + c \sin \text{phi}$. This leads to an egg-shaped cross-sectional contour.

Inconcentricity of the second order means that the cross-sectional contour in each axial position of the cross-sectional plane, shown in polar coordinates, has a radius R according to a function $R = R_m + c \sin(2 \text{ phi})$. This leads to an elliptical cross-sectional contour.

Analogously, a third-order inconcentricity means that the cross-sectional contour in each axial position of the cross-sectional plane in polar coordinates shows a fluctuating radius according to a function $R = R_m + c \sin(3 \text{ phi})$. This leads to a cross-sectional contour similar to a strongly rounded triangle.

One might proceed correspondingly up to even higher orders, but as a rule these no longer play any great role; lowering of the amplitude of the first harmonic is most important.

With a device according to Claim 22, at the sites of greater curvature of the drum in cross-section, thus at the maxima of R, a greater pressure is built up between the bead core and the bead seating surface than at the sites of lesser curvature in the drum cross-section. There also at least more or less rubber is only displaced there, and this even if the processed tire bead is not hot locally, but is uniformly hot between 100°C and 230°C. In this way

therefore a process according to Claim 3 can be performed. Localization of the heat effect is additionally possible, for example through thermal conduction of different strengths.

One advantage of a device according to Claim 21 as well as Claim 22 is the possible monolithic nature of the conical drum, so that the construction expense is especially low and no gaps between segments must be taken into consideration or bridged. A disadvantage, however, is the gliding movement on the inner bead seating surface, requiring lubrication thereof.

For performing the second process variant according to Claim 20, thus with a shrinkage instead of an expansion of the lumen of the bead, in place of a conical calibrated rim or a drum, by which all segments are moved out an equal distance over a corresponding forced control, a device would be necessary that has two rings, similar to clamping jaws, per bead, which are axially movable relative to one another, and in the case of such movements, squeeze together the corresponding bead cord between the two. For this only one of the two rings need be movable, and none of the rings need to be broken down into segments.

The last-mentioned construction form of the two rings to be moved axially toward one another, broken down into segments, leads to a particularly low construction cost and—according to the split- and edge-free design—a particularly good surface quality of the finished tire bead; a device carried out in this way is the object of Claim 23.

The plastic reforming on moving together the two rings that axially compress a bead essentially takes place in the regions in which a particularly large amount of material is located on the side of the bead core and correspondingly as a rule particularly little material

beneath the bead core. As a result the uniformity of path in the reforming leads to making the geometry more uniform.

The device according to Claim 23 can be modified in that the two rings, grasping a bead each, are not designed coaxially but with an adjustable axial displacement to one another leading to the device according to Claim 24, which is suitable for performing processes according to Claim 6 and/or 7.

"Deaxiability" means that the axes of rotation of the two rings to be sure meet at a point located at half of the mean distance between the two rings (which implies "concentric"), but also meet only at one point, thus do not coincide (which would be called "coaxial"), but stand at an adjustable acute angle to one another. If the device were allowed to rotate, at least one of the two rings would appear to be tumbling. The word "tumbling" in the characterization of Claim 24 is in itself superfluous; it is only there because sometimes the words "deaxial", "deaxialized" and "deaxiable" in German are not distinguished so sharply from "eccentric" etc. as is actually correct. The combination of the terms concentric and coaxial could also be designated as "being in alignment."

This method of carrying out the process, to be sure, makes it possible only to combat the first and not the higher harmonics of the radial force fluctuation or the radial fluctuation, but on the other hand the devices required for this purpose can be produced particularly economically, are particularly reliable in operation, and a first-class surface quality results, which is ultimately due to the one-piece nature of the pressing rings.

In the following, universally usable devices will be described, which especially also make it possible to combat higher harmonics but are also more expensive because of their multipart nature.

For the process variants in which rubber is pressed from radially inside to radially outside, thus process variants according to Claim 3 and/or 4, the multipart device also has the shape of a drum. The latter has at least two segments, at least one of which must be radially movable; preferably it should have several segments, particularly preferably twelve. Preferably all the segments are radially movable.

Drums with these features are known in and of themselves and are currently used in the tire industry to construct tire blanks.

To be usable for the process in accordance with the invention, such drums must be able to apply considerably greater spreading forces without damage, namely such as those that result after multiplying by the respective circumferential length from Claim 5. The load-bearing ability of the drums required for carrying out the process in accordance with the invention is more than two powers of ten above that of previously known drums. Even in terms of the dimensions of their spreading mechanisms, the drums to be newly produced here according to Claim 25 that are under discussion thus differ considerably from those previously known in the tire industry.

Unless the possibility of vulcanization heat utilization according to Claim 18 is used, drums for performing the process also require the heatability of at least one—and preferably all—of their segments according to Claim 26. Thus the segment surface that is designed for contact and plastically deforming pressing on the essentially axially extending bead seating

surface of at least one of the segments can be heated such that a temperature of between 100°C and 230°C, preferably between 160°C and 180°C can be reached.

However, if use is to be made of the possibility of vulcanization heat utilization, a single segment need not be heatable; as previously mentioned, such designs are preferred in industrial scale manufacturing and after-treatment.

With regard to process control, to make possible a process design according to Claim 19, in accordance with Claim 27 drum designs are preferred in which at least one—preferably all—of their segments is or are able to be cooled in such a way that their segment surface(s) which is or are provided for contact and plastically reforming pressure on the essentially axially extending bead seating surface can reach a temperature of less than 100°C, preferably less than 75°C.

For carrying out a process in analogy to Claim 20, as an equivalent replacement for a conical calibration rim, the use of such a drum would also be possible, all segments of which can be moved apart over an appropriate force control. The plastic reforming then takes place essentially in the regions in which a particularly large amount of material is located below the bead core.

Such drums, which can only be uniformly spread over the circumference, are also usable for the process variants where the temperature exposure takes place locally, whether through local heating or through cooling at complementary sites.

Particularly preferred, however, are drum designs in which, according to Claim 28, the segments can be moved out for different distances. In this way it is possible precisely and for

almost all cases to achieve the optimal local distribution (briefly described in this application as "localizability") of the reforming force.

For the process variants in which rubber is pressed radially inward from the sides, thus process variants according to Claim 6 and/or 7, the multipart device also has a form that could be designated as a vise with annular clamping jaws. However, since only vises with short, straight clamping jaws seem to be known, only the more general term "device" will be used here.

A device of this type according to Claim 29 has at least two rings for grasping a tire bead, wherein at least one of the rings is broken down into at least two, preferably twelve segments, at least one of which can be moved axially. Preferably all axial segments of one or both rings are axially movable.

In principle it would already be sufficient if only segments of one of the two rings interacting for each bead are axially movable, preferably the segments of the axially inner ring. On the axially inner side, specifically, the possible setbacks at the segment boundaries—especially in the case of clearly differing move-out distances of adjacent segments—and remote burrs resembling excess rubber are less interfering than on the axially outer side, where they can interfere with the flush positioning of the unit between the rim horn and the tire bead.

In addition, to avoid setbacks and burrs, it is also possible to use devices—exactly like those which press from radially inside to radially outside—that have a smoothing rubber ring or a smoothing rubber cuff over the segments, preferably made of metal, so that these

relatively hard segments do not act directly on the bead to be plastically reformed but rather only over the smoothing rubber component.

Especially large displacements of the bead core away from the bead seating surface are possible when, according to Claim 30, the segments of both rings located axially opposite from one another move axially toward one another. In this process it is possible to combat with the segment positioning of the outer ring axially only long wave disturbances, preferably only those of the harmonic, but in the case of the segment positioning of the axially inner ring to combat shorter wave ones, preferably to provide two maxima, one of which is in the same phase as the preferably single maximum in the segment positioning of the axially outer ring.

It is also possible, when using two rings of axially movable segments, that only one of the rings, and then preferably the axially outer one, to have an edge-compensating rubber ring on its side facing the bead to be processed.

In that case, in analogy to the drums and to Claim 26, the vise-like devices discussed here for axial bead compression, when the possibility of using the heat of vulcanization according to Claim 18 is not utilized, require the heatability of at least one and preferably all of their segments according to Claim 31. Correspondingly, at least one—preferably all—of their segments is or are heatable in such a way that its or their heating surface(s), which is (are) provided for contacting and imposing a plastically reforming pressure on the essentially radially extending surfaces, can reach a temperature between 100°C and 230°C, preferably between 160°C and 180°C.

However, if the possibility of using the heat of vulcanization is to be employed, a single segment need not be heatable, as was stated analogously in the case of the radially

pressing drums. As was already outlined during the description of the process embodiments according to Claims 18 or 19, such embodiments are preferred in large series manufacturing and after-treatment.

With regard to a process procedure to make possible a process design according to Claim 19, according to Claim 32—in analogy to Claim 27 for drums—device designs are preferred in which at least one—preferably all—of their segments is or are able to be cooled in such a way that their segment surface(s), which is or are provided for contacting and plastically reforming pressure on the lateral, essentially radially extending bead surfaces, can reach a temperature below 100°C, preferably below 75°C.

The greatest flexibility in use—naturally also allowing for the greatest construction expense—exists for drums according to Claim 33, in which each of their segments can be adjusted to various temperatures by independent heating and/or cooling.

Like all multi-part, plastically reforming tools, the multi-part drums and rings treated in this application also have the problem that edges can be pressed into the bead in the work piece being reformed, which are undesirable, and especially are undesirable on the radially inner bead seating surface, where the currently customary tubeless tires reach the required airtightness with regard to the rim. At other points in this application it has already been suggested that these edges and gaps be cushioned or covered with rubber cuffs.

Claim 34 mentions as an alternative to "take back" the tool surfaces that make contact in the vicinity of their borderlines, in other words in the vicinity of the borderline to make the segments move out so gently that they no longer exert a pressure sufficient for reforming

there. Specifically applied to the case of a drum, this means that the segments moving toward one another should also be flattened at their borderlines, also known as joint sites.

To reduce the forces required for reforming and especially to further increase the reproducibility of the plastic reforming achieved on the finished, vulcanized bead tire, it is advisable according to Claim 35 to make the bead vibrate, preferably in the ultrasonic range, at least in parts—especially naturally in the areas in which the only or largest deformation is to be achieved during the ongoing plastically reforming after-treatment. This can be achieved by a high frequency alternating magnetic field acting on the iron-containing bead core. The force attack can thus first take place by electrical and/or magnetic alternating field, and only be performed by this on the bead rubber to be shaped.

If such a field is applied in the revolving or rotating condition, this can also be used simultaneously for inductive heating of the bead, wherein in this way a heat flow from the bead core to the bead surface is achieved.

A local (= systematic) vibration introduction, thus non-uniform over the circumference, on the other hand seems more easily achievable through the fact that at least one of the components that makes contact with the bead during the plastic reforming vibrates.

In the following, the invention will be explained on the basis of some figures. These show:

Fig. 1 A known pneumatic vehicle tire with an RKS, by which the maximum of the first harmonic is marked,

Fig. 2 The corresponding RKS recording and the corresponding first harmonic,

Fig. 3 Schematically a device that can be used for reducing the maxima of the first harmonic and—with a slight modification—of the second harmonic as well, specifically by means of radial force application,

Fig. 4 The device according to Figure 3 in action for reducing the first harmonic,

Fig. 5 For comparison with Figure 2, the RKS recording achievable in this way,

Fig. 6 Schematically a device that can be used to raise minima of the RKS recording by means of axial force application,

Fig. 7 In an enlarged cutout from Figure 6, the bead region of the tire to be treated and the two tools ready for action and

Fig. 8 In analogy to Figure 7, the same tire area after completion of the bead treatment with the tools still in place.

Figure 1 shows a known pneumatic vehicle tire 1 with a bead 2. The tire 1 has a radial force fluctuation (equals RKS). The site of the maximum of this RKS is clearly indicated by a mark 10 on a tire sidewall 5 on tire 1. RKS analyses and the devices advantageous for this are well-known to experts; they are described, for example, in DE-OS 4,339,775.1 A1.

All of the marks 10 should be designed such that they can be read both by the operating personnel—without any auxiliaries such as a magnifying glass, goggles, magnetic field detector, etc.—as well as by automated machines. Preferably as the markings 10, imprinted removable stick-on labels are used in such a way that for the subsequent treatment steps a coded data extract from the RKS analysis is present.

Preferably the data coding takes place in a form such that the site of the maximum of the first harmonic is marked, for example with a red circle, within which the amplitude of indicated by height.

The marking of the minimum of the first harmonic is no longer necessary thereafter, since by definition it is phase shifted by 180°. The marking of the minimum is recommended, however, since on one hand a redundancy is achieved in this way (for example if one stick-on label is accidentally pulled off, seen by someone on the floor, and stuck back on again, but unfortunately at the wrong place, the redundancy would reveal such an error), and on the other hand the possible alternative or additional treatment of the minimum is facilitated.

For example, a green X might be suitable for marking the minimum of the first harmonic, on which the amplitude amount (naturally the same aside from the sign in front of it) is likewise marked.

If the price obtainable for the tires also permits the testing and possible the treatment of the second harmonic, again with a red double circle (either two circles side by side or preferably two concentric circles of different sizes), the two maxima of the second harmonic can be marked, and with a green double cross the two minima of the second harmonic. In or on these marks as well, the corresponding amplitude should be given.

Analogously it would be possible to mark the extrema of the third harmonic with three concentric circles or with XXX and then treat them; according to estimates to date, however, tire buyers are not prepared to pay for this.

The term "harmonic" is always used here in regard to and in agreement with Fourier analyses. Thus the first harmonic is a sine wave over the angle of rotation with amplitude and phase position determinable according to Fourier and with a period length of 360°; the second harmonic is a sine wave over the rotation angle with amplitude and phase position determinable according to Fourier and with a period length of 180°; the third harmonic is a sine wave over the angle of rotation with amplitude and phase location determinable according to Fourier and with a period length of 90° and so forth. The actual RKS recording should thus first be subjected to a Fourier analysis. As a rule, this analysis can be stopped even after the second harmonic.

Figure 2 shows, in a solid line, such an RKS recording for tire 1 according to Figure 1. Its maximum lies at -5° and amounts to about 6.6 daN (each horizontal scale marking stands for 2 daN). The corresponding first harmonic is shown in a broken line. Its maximum falls at about 40° and amounts to about 5.4 daN. Thus its minimum lies at 220° and -5.4 daN.

After harmonic analysis of the RKS recording, for each individual tire or for groups of tires a decision is made regarding whether and if appropriate which bead-reforming after-treatment it will be subjected to. Negligible errors are not treated at all; in the case of tires with small errors (as long as the quality requirement pertains only to the first harmonic as usual) only either the minimum or the maximum of the first harmonic should be treated, or in the case of tires with moderate errors, both extrema of the first harmonic. Tires with larger errors are to be avoided by other measures.

For the case of smaller errors, especially frequent in our plants, for which the possibility exists of choosing between a maximum reduction and a minimum increase, it is advisable to check the so-called bead labeling, thus the thickness of the bead pressing on a standard measuring rim. If the pressure is higher than the mean pressure in the normalized interval, the RKS maxima should be made smaller, but on the other hand if the pressure is lower than the mean one in the normalized interval, RKS minima should be increased.

Figure 3 shows schematically a device that can be used to reduce the maxima of the first harmonic and—in a slight modification—also of the second harmonic and specifically by means of a radial force attack; the later Figures 6, 7, and 8 will show the treatment possibility of the minima.

The drum-type device shows a segment 11 shown from the top and a segment 12 shown from the bottom. In the position shown, the two segments are practically brought together. The upper segment 11 shows in the center of its arc length an electrical resistance heater 13, which is regulated by a thermostat at 160°C. The lower segment 12 has a temperature of about 20°C.

If in a manufacturing line, for lack of space, the tire must be treated in a rapid sequence even shortly after vulcanization, the possibility of cooling the lower segment is advisable to maintain such a temperature.

True to the generally applicable principle that heating is cheaper than cooling, the heat of vulcanization is generally not used for combatting the first harmonic, thus the tire is allowed to cool naturally until its periphery has reached about 30°C for passenger vehicle tires and about 25°C for truck tires. Then the tire is pulled onto the device according to Figure 3

and simple convection cooling of the lower shell is utilized—especially reached in the standstill times—and thus forced cooling with cooling coils and compressors or the like is avoided.

If, as shown in this figure, only one of the two segments is heated, a bead forming is achieved on this also. On the unheated segment as well, to be sure the tire bead undergoes the same pressing, but unless the elevated temperature is added, this leads to practically no permanent deformation.

The device shown here is only suitable for treating the first harmonics; with incorporation of an additional electrical heater, namely also in the segment 12 shown at the bottom, it would be suitable for treating the second harmonic. If both segments 11, 12 were now spread, a plastic bead reforming would be achieved in the center of the two segments 11, 12 because of adequate pressing force and heat. 90° and 270° phase shifted to this practically no deformation is achieved, since the segment temperature there is scarcely elevated and in addition pressing scarcely exists.

If the two heaters are made separately switchable, the device can be used as needed both for combatting the first harmonic (for the purpose of which precisely one segment is heated) and for combatting the second harmonic (for the purpose of which both segments are heated, especially in their central region).

If both the amplitudes of the first and the second harmonics are to be reduced, and if this is to take place in a collective treatment, thus without RKS measurement of each individual tire (tires to be measured and therefore to be placed under a stress must be cool), this preferably takes place in the sequence that first the amplitude of the second harmonic is

reduced, and only then that of the first harmonic. To be sure, technicians are accustomed to do the most important thing first—here, reduction of the first harmonic—but with the above-recommended inverse sequence, reduced costs result, especially for heating energy, as explained in the following.

Soon after their vulcanization, thus while still hot, the tires are placed on the device according to Figure 3. The electrical power uptake of the heaters of both shells 10 and 11 are then considerably reduced compared to heating at 20°C, thus only temperature deviations that may have been developed need to be compensated by different lengths of residence time after completion of vulcanization. After that the tires are allowed to cool at rest in order to treat the first harmonic, proceeding from the cold tire.

Where on the other hand—for example by means of an available cool water flow—in exceptional cases cooling is cheaper than heating, then even odd-numbered harmonics, especially the first one, can be reduced by systematic cooling of the segment that is not to be formed rather than systematic heating of the segment that is to be reformed.

To avoid damage to the radially inward bead surfaces of the tires to be treated, the segment 11 at its two jacket edges has flattenings 11.1; the unheated segment 12 also has analogous flattenings 12.1 for the same purpose.

Figure 4 shows the device according to Figure 3 in action: For this purpose the pneumatic vehicle tire 1 from Figure 1 has been pulled onto the device. To reduce the first harmonics of the RKS the tire is rotated such that its RKS maximum previously marked with the mark 10 comes to lie exactly in the middle of the heated segment 11 of the device. Then the two segments 11 and 12 were moved radially away from one another in a measured

fashion with a spreading, radial force Fr; they are shown here in this separated position. Thus especially at the zenith of the two segments 11 and 12 a high pressure acts on the essentially radially extending bead seating surfaces 7a.

Figure 5 shows—for comparison with Figure 2—the RKS record now achieved: in the range around 40° the amplitude of the RKS recording is reduced, specifically

at -20° and at 100° by about 0.3 daN,

at -10° and at 90° by about 1.1 daN,

at 0° and at 80° by about 2.3 daN,

at 10° and at 70° by about 3.7 daN,

at 20° and at 60° by about 4.9 daN,

at 30° and at 50° by about 5.7 daN, and

at 40° by about 6.0 daN.

The maximum of the lowering 9 thus, according to phase, is located at the maximum of the first (untreated) harmonic, thus 40°. Also according to quantity the maximum of the lowering falls at the maximum of the first (untreated) harmonic, preferably somewhat greater, here about 6.0 daN.

For the purpose of easier comparison with Figure 2, which showed the initial state, the heavy, solid abscissa axis is placed such that outside the treatment region, thus from 100° to 340°, uniformity of coverage exists between Figure 2 and Figure 5 when the abscissa axis, drawn solid here, is brought to coincide with the abscissa axis from Figure 2.

However, since naturally the mean wheel load remains unchanged, the integral of the radial force fluctuation over a period length thus by definition must be exactly zero, the

actually applicable abscissa axis is located somewhat lower, specifically by the integral of the two equations previously given for the lowering function over dphi divided by 360°.

If the device were also to be used for reducing the amplitude of the second harmonic, first of all the amplitude and phase position of this second harmonic must be detected, correspondingly the tire to be treated must be turned into the correct angular position relative to the device and then this treatment must be performed. In treatment of the second harmonic, where indeed in the zenith of the two device segments a plastic reforming of the bead in accordance with the invention must be achieved, both segments must be hot. It may be advisable by means of another heating coil—concentrated spatially more sharply on the respective zenith—to concentrate the heat effect more strongly on the zenith.

Figure 6 schematically shows a device that is used to raise minima of the RKS recording by axial force action. It shows two axially outer shells 14 and 16, each of which has on their sides facing one another, thus the axial insides, a groove 17 opening axially toward the inside, the cross-sectional shape of which is equal to the negative of the bead contour on its radially inner side and axially outer side.

Between the two outer shells 14 and 16 in each case a center shell 15 is arranged. On its two axially outer edges this has in each case a groove 18 of lower depth. With this groove surface the respective axially inner side surface of the bead 2 of the tire to be treated is grasped.

The plastic bead reforming in accordance with the invention is now achieved by moving the two outer shells 14 and 16 together. Advantageously their angular position can be freely adjusted in a small angular range by a ball joint or cardan suspension. In a first step

these outer shells 14 and 16 are brought together only to such an extent that—with the mediation of the left clamped-in bead 2, the center shell 15 (which may remain rigid) and the right bead 2—a pressing force is generated which is at least large enough to over come the loosening moments of the jointed support based on frictional adhesion, but relative to the temperature is small enough to generate no plastic bead reforming as yet. The angular position of the outer plates 14 and 16 relative to the center plate 15 that becomes established hereby is stored.

This mentioned first step with low force serves to calibrate the null value of the plate angle subsequently to be set. If in a tire buildup machine—especially an automatically controlled one—the overlapping points are always at the same location and the overlapping widths from tire to tire are always the same, it is also sufficient if this first calibrating step is only performed for the first one, and then is only checked randomly thereafter.

Beginning from the neutral position of the outer shells 14 and 16, which act as pressing jaws, and which [position] is always obtained in the individual case as usual, these [shells] are then declined.

Here, "declination" means an oblique positioning of the outer shells 14 and 16 at an angle alpha such that in the areas brought closer to the center shell—which lie where a radial force minimum existed before the treatment—the bead is pressed so strong axially in proportion to the bead temperature that a plastic reforming occurs. The rubber pushed away locally in this case primarily reaches the radially internal side of the bead and there—after mounting on a rim—increases the distance between the bead core and the approximately axially traveling tire seating surface on the rim. In this way at such locations, the tread

surface attached over the carcass threads also goes to a larger radius, which brings about a locally increased radial force, thus a reduced radial force minimum.

In this process it is possible both to decline the outer plates under a load and to first decline them without a load, to arrest them at the declination angle relative to an axially guided pressing piston, and then to place them under load over the pressing piston that travels axially inwardly.

As was already mentioned in the general section of the specification, alternatively or as a supplement to the declination, local concentration of the heat onto the areas to be reformed is also possible; however, this means somewhat smaller reproducibility insofar as fluctuations arise in the chronological sequence due to pauses, delivery times, and the like.

Figure 7 shows in an enlarged cut-out from Figure 6 one bead (namely the left-hand one) 2 of the tire 1 to be treated with a pierced bead core 3 embedded therein, on which a radial carcass 4 is anchored by looping. For the plastic reforming of this bead 2 in accordance with the invention, the left shell 14 with its groove 17 and the center shell 15 with its groove 18 are available.

The two shells 14 and 15, visible only in sections here, are moved together just far enough so that they stop axially outside the bead 2 between the groove 18 of the shell 15 and the radially outer zone of the groove 17 of the shell 14 with slight pressure through an axial force Fa. The radially inner seating surface 7a of the bead 2 on the other hand does not yet touch the corresponding zone of the groove 17 of the left shell 14. Between the contact surfaces 20 and 21 of the shells 14 and 15 (and naturally also between the shells 15 and 16 not visible here), a gap 19 remains in this initial phase.

Figure 8 shows, in analogy to Figure 7, the same tire region, but after the two shells 14 and 15 have been moved together. The maximum possible travel distance of the shell 14 to the right against the shell 15 is limited by the contact surfaces 20 of the left-hand shell 14 and 21 of the center shell 15. Here, the extremely possible procedure is shown, according to which the two stop surfaces 20 and 21 lie on one another, thus the gap 19 still visible in Figure 7 has disappeared. However, this representation should not mean that the maximum possible travel distance must be utilized in each case; instead the size of the local travel distance is to be adapted to the amplitude of the first harmonic of the radial force fluctuation (RKS) of the bead 2 of the tire 1 that is to be reduced.

The shells 14 and 15 (and naturally the shell 16 not visible here) are hot especially in the circumferential region in which the tire is to be reformed. The shells can also be locally uniformly temperature-controlled, so that the local differentiation between no, slight, and large bead reforming is achieved only by the different sized pressing force distribution.

The different sized pressing force in this device, as is apparent from Figure 6, is achieved by the inclined positioning of the outer shells by an angle alpha; here this angle alpha between the left-hand shell 14 and the center shell 15 need not agree with the other angle alpha between the middle shell 15 and the right-hand shell 16. Instead, with even more accurate differentiation, different sized radial force fluctuations in a left and a right measurement track can be combatted, thus a conicity of the tire 1 fluctuating over the circumference. It is even possible within narrow limitations to reduce a conicity present over the total circumference if the treatment of one of the two beads would suffice for reducing the radial force fluctuation.

After the reforming shells 14 and 16 have remained for a certain length of time—about 20 minutes—in the position brought together as shown in Figure 8, the bead treatment can be completed; for this purpose, the shells 14 and 16 are moved axially outward again and the tire 1 removed.

The exemplified embodiments shown should not limit the protective scope of this invention. Instead they should serve only for further explanation. The dimensions mentioned were tested in initial experiments and confirmed. The essential point of the invention is that in a process for bead after-treatment to improve the tire uniformity, instead of the previously known, regional grinding off of the bead surfaces, a regional plastic reforming of the bead occurs. In this way it is not only possible to reduce radial force maxima as with grinding, but also to raise radial force minima.

A list of symbols is a component of the specification.

List of Symbols

1	tire
2	bead of the tire 1
3	bead core
4	carcass
5	side walls

7 seating surfaces of 2

7a radially interior, essentially axially traveling seating surface of each bead 2 (for short: bead seating surface)

7b axially outer, essentially radially traveling surface of each bead 2

7r axially inner, essentially radially traveling surface of each bead 2

9 lowering function over the angle (see broken line in Figure 5)

10 markings = marks of RKS extrema

11 upper segment of a radially acting bead pressing device

11.1 flattening on the jacket edge of 11

12 lower segment of a radially acting bead pressing device

12.1 flattening on the jacket edge of 12

13 electrical resistance heating in segment 11 and possibly (for also treating the second harmonic) also in segment 12

14 left axially outer shell of the device according to Figure 6 and 7 for axial bead pressing

15 center shell of the device according to Figures 6 and 7 for axial bead pressing

16 right axially outer shell of the device according to Figures 6 and 7 for axial bead pressing

17 groove in axially outer shells 14 and 16 of the device according to Figure 6 for receiving the bead 2 of the tire 1

18 grooves in axially central shell 15 of the device according to Figure 6 for receiving the bead 2 of tire 1

19 gap between the stop surfaces 20 and 21 in Figure 7

20 stop surfaces on left-hand shell 14

21 stop surfaces on center shell 15

Fa force pressing from axially inside to axially outside against 7r and from axially outside to axially inside against 7b

Fr force pressing from radially inside to radially outside against 7a

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Claims:

1. Process for improving the concentricity of a vehicle tire (1), wherein its bead (2) is subjected to an aftertreatment after vulcanization that improves the concentricity, characterized in that during the aftertreatment the bead (2) is plastically reformed, at least in some areas.

2. Process in accordance with claim 1, characterized in that no material is removed during the aftertreatment.

3. Process in accordance with claims 1 and 2, characterized in that
   - the regional reforming of the bead (2) takes place by local action of a force component (Fr) extending from radially inside to radially outside against the essentially axially extending bead seating surface (7a) and through the action of heat.
   - after which, at the site of this action, the bead core (3) of the aftertreated tire (1) is located closer to the essentially axially extending bead seating surface (7a) than before the treatment.

4. Process in accordance with claims 1 and 2, characterized in that
   - the regional reforming of the bead (2) takes place by action of a force component (Fr) extending from radially inside to radially outside against the essentially axially extending bead seating surface (7a) and through local action of heat;

- after which at the site of action the bead core (3) of the aftertreated tire (1) is located closer to the essentially axially extending bead seating surface (7a) than before the treatment.

5. Process in accordance with claim 3 or 4, characterized in that
   - the radially outward pressing force component (Fr) amounts to between 50 and 150 N per mm circumferential length of the sector of the essentially axially or radially extending bead seating surface (7a) in which the plastic reforming of the bead (2) is to take place, and
   - the heat at least in the area of the bead (2) amounts to between 100°C and 230°C—preferably between 160°C and 180°C,
   - wherein the duration of the joint action of force and heat amounts to between 10 minutes and 45 minutes.

6. Process in accordance with claims 1 and 2, characterized in that
   - the regional reforming of the bead (2) takes place by local action of a force component (Fa) compressing the bead (2) to be treated together on its essentially radially extending surfaces (7b, 7r) and through the action of heat,
   - after which at the site of this action, the bead core (3) of the aftertreated tire (1) is located farther away from the essentially axially extending bead seating surface (7a) than before the treatment.

7. Process in accordance with claims 1 and 2, characterized in that

- the regional reforming of the bead (2) takes place by the action of a force component (Fa) axially compressing the bead (2) to be treated on its essentially radially extending surfaces (7b, 7r) and through local action of heat.
- after which at the site of this action the bead core (3) of the aftertreated tire (1) is located farther away from the essentially axially extending bead seating surface (7a) than before the treatment.

8. Process in accordance with claim 6 or 7, characterized in that

- the axially compressing force component (Fa) amounts to between 50 and 150 N per mm mean circumferential length of the sector of the essentially radially extending bead seating surface (7r) in which the plastic reforming of the bead (2) is to take place, and
- the heat, at least in the area of the bead (2), amounts to between 100°C and 230°C, preferably between 160°C and 180°C
- wherein the duration of joint action of force and heat amounts to between 10 minutes and 45 minutes.

9. Process in accordance with claims 1 and 2 and at least one of the claims 3 or 4, characterized in that

- first in a manner known in and of itself the site(s) is (are) determined at which a radial quantity [R] of the tire (1)—preferably its radial force—exceeds a threshold value;

- thereafter, at least at the point where this radial quantity [R] of the tire (1) exceeds the threshold value and is largest, preferably at all points where the radial quantity [R] is too large, exceeding a threshold value, the radial quantity [R] of the tire (1) is reduced;
- specifically, it is reduced there in such a manner that the bead core (3) there is brought close to the essentially axially extending bead seating surface (7a).

10. Process in accordance with claims 1, 2, and at least one of the claims 6 or 7, characterized in that
    - first, in a manner known in and of itself, the point(s) is (are) determined at which a radial quantity [R] of the tire (1)—preferably a radial force, but also possibly its tread radius—falls below a threshold value,
    - then at least at the point where this radial quantity [R] of the tire (1) drops below the threshold value and is smallest, but preferably at all points where the radial quantity [R] is too small, dropping below a threshold value, the radial quantity [R] of the tire (1) is increased,
    - and specifically, is increased in that the bead core (3) there is brought farther away from the essentially axially extending bead seating surface (7a).

11. Process in accordance with claims 1 and 2, and at least one of the claims 3 or 4, characterized in that
    - at first a radial quantity [R] of the tire—preferably its radial force—is determined over at least one complete wheel revolution as a function of the wheel rotation angle (phi),

- thereafter by means of a Fourier analysis, at least the first—and preferably the first, second, and third—harmonics of this function is/are determined,
- thereafter at least in the area of the maximum of the first harmonic—preferably also in the area of the maximum of the second and in the area of the maximum of the third harmonic—this radial quantity [R] of the tire (1) is reduced,
- and specifically is reduced there in that there the bead core (3) is brought closer to the essentially axially extending bead seating surface (7a).

12. Process in accordance with claims 1, 2, and at least one of the claims 6 or 7, characterized in that
    - at first a radial quantity [R] of the tire—preferably its radial force—is determined over at least one complete wheel revolution as a function of the wheel rotation angle (phi),
    - thereafter by means of a Fourier analysis, at least the first—and preferably the first, second, and third—harmonics of this function is/are determined,
    - thereafter at least in the area of the maximum of the first harmonic—preferably also in the area of the maximum of the second and in the area of the maximum of the third harmonic—this radial quantity [R] of the tire (1) is increased,
    - and specifically is increased there in that there the bead core (3) is brought farther away from the essentially axially extending bead seating surface (7a).

13. Process in accordance with claims 9 and 10 or according to claims 11 and 12, characterized in that both the maximum of the radial size [R] and the maximum of the

first harmonic of the radial size [R] is reduced and the minimum of the radial size [R] and the minimum of the first harmonic of the radial size [R] are increased.

14. Process in accordance with one of the claims 9 to 13 and claim 5 or 8, wherein as the radial quantity [R] the radial force [R_f] with its fluctuation [δR_f or—meaning the same thing—RKS] is recorded, characterized in that

- first the orientation and height of the advantageous radial force change δR is determined—preferably according to one of the claims 7 to 11,
- then, depending on the planned reforming temperature T, the required contact time is determined according to the following formula

  where c is a constant that depends on the rubber mixture and T_0 is the glass transition temperature of the rubber mixture used in the bead region, wherein for the rubber mixtures that are customary in the tire bead region, the constant c is between 1.0 and 2.8 x 10^{-7} mm^2/K^2sec, and for most automobile tires is between 1.6 and 1.8 x 10^{-7} mm^2/K^2sec
- and thereafter the pressure and heat treatment of the tire bead (2) planned according in this way is performed.

15. Process in accordance with claim 14, characterized in that

a) in the finishing of all tire blanks of a batch, the required joining sites be arranged in respectively the same phase position and

b) that all tire blanks of this batch be placed in a similar—preferably the same—vulcanization mold in a determined phase position and vulcanized,

c) that after this a representative population of n tires—wherein n is preferably equal to 8—is removed from this batch,

d) and all tires of this batch are cooled—preferably below 75°C,

e) after which each tire of this group is pulled onto a measurement rim and for each tire of this group a radial quantity [R_μ]—preferably the radial force—is measured over the angle of rotation (phi), wherein μ is to run from 1 to n,

f) after which these individually determined function courses of the radial quantity $R_\mu = f_\mu$ (phi) are averaged in a phase-correct, linear way to form a mean radial quantity

$R_m = f_m$ (phi) = $1/n \times [R_1 + R_2 + \ldots + R_{(n-1)} + R_n]$,

g) after which, depending on the mean radial quantity R_m(phi) determined in this way, the plastic bead reforming—in the preferred case according to Claim 14—is determined and subsequently the plastic bead reforming determined in this way is performed on all n tires of this group,

h) after which each tire in this group is cooled again—preferably below 75°C, once again drawn onto a measurement rim, and for each tire in this group once again the radial quantity [R] measured over the rotation angle (phi) and compared with predetermined tolerance fields, and

i) in the case of maintenance of predetermined tolerance fields, all remaining tires in this batch are treated in the same way to reform the bead (2) plastically in certain regions.

16. Process in accordance with claim 15, characterized in that

- in the case of mon-maintenance of the predetermined tolerance fields in accordance with feature h) of the preceding claim, an additional representative population is removed from this batch,
- wherein the additional population mentioned contains no tires from the first population,
- after this, the additional population mentioned is treated according to the features d) to h) of the preceding claim,
- after which, if predetermined tolerance fields are maintained, all the remaining tires of this batch are treated in the same way, regionally plastically reforming the bead (2).

17. Process in accordance with one of the preceding claims, characterized in that a radial quantity R(phi)—preferably the radial force—is measured in two tracks Rr(phi) and Rl(phi), namely one to the right and one to the left of the tire center, and in the case of deviations between Rr and Rl, both beads (2) of the tire (1) are plastically reformed differently from one another, wherein the arc length region(s) in which the one bead is plastically reformed can deviate from the arc length region(s) in which he other bead is plastically reformed.

18. Process in accordance with at least one of the Claims 3 or 4 or 6 or 7, and also preferably according to Claim 15, characterized in that—in the case of claim 15 aside from the tires of the representative population(s)—the tires in a batch are slowed in their cooling

— by sufficiently short time intervals between removal from the vulcanization mold and performance of the at least regional plastic bead reforming and/or

— by thermal insulating means, usually surrounding the tire beads

— to such an extent that the tires, at least in the bead region on pulling onto the device that brings about bead reforming, without supply of heat energy into the tire bead, still have a temperature between 100°C and 230°C, preferably between 160°C and 180°C.

19. Process in accordance with Claim 18 and at least one of the claims 4 or 7, characterized in that the localization of the influence of heat is achieved in that before applying the reforming force, the regions of the bead (2) that are to remain essentially non-reformed are cooled, preferably to a temperature below 75°C.

20. Process in accordance with Claims 1 and 2, characterized in that the material distribution in the core region is made more uniform by uniformly expanding the tire bead, for example by pressing onto a conical calibration rim, or by uniform axial compression, in each case at a bead temperature between 100°C and 230°C.

21. Device for performing a process in accordance with Claim 20 with uniform radial bead expansion, which comprises a drum that is not subdivided into segments that are movable mechanically with respect to one another,

characterized in that the drum is conical—preferably with an angle (ß) between the jacket surface of the drum and the rotational symmetry axis corresponding approximately to the inclination of the radially inner bead seating surface of the tire to be treated—and is (segmentally or totally) heatable or coolable or thermally insulating, wherein the device also has a—preferably annular—element that is capable of axially pressing on a tire bead.

22. Device in accordance with claim 21, but for nonuniform radial bead expansion in accordance with claim 3 or 4, having a drum that is not subdivided into segments movable mechanically with respect to one another,

characterized in that

- the drum is conical—preferably with an angle between the jacket surface of the drum and the rotational symmetry axis corresponding approximately to the inclination of the radially inner bead seating surface of the tire to be treated
- whereby the drum is non-round in cross section, in other words, to combat a first harmonic is egg-shaped, to combat a second harmonic is ellipsoidal, and so forth.
- wherein the drum also has a preferably annular element that is capable of axially pressing on a tire bead (2),
- wherein the drum preferably—segmentally or overall—is heatable or coolable or thermally insulating.

23. Device for performing a process in accordance with Claim 20 for uniform axial bead pressing, which comprises at least two annular shells (14, 15, 16) that are not subdivided into segments movable mechanically with respect to one another, characterized in that both shells (14 and 15; 15 and 16) are conveyed coaxially and concentrically with respect to one another and have surfaces (17 and 18) facing one another that fit as negatives to the axially inner and axially outer bead contours of the tire to be treated, and preferably —segmentally or overall—are heatable or coolable or thermally insulating, wherein at least one (14, 16) of the two shells (14, 15, 16) acting on a bead (2) is axially movable with respect to the base of the device.

24. Device in accordance with Claim 23, but for nonuniform axial bead pressing according to claim 6 or 7, wherein the device comprises at least two shells (14, 15, 16) that are not subdivided into segments movable mechanically with respect to one another, characterized in that both shells (14 and 15; 15 and 16) have surfaces (17 and 18) facing one another that fit as negatives to the axially inner and axially outer bead contours of the tire to be treated, and preferably, wherein both shells (14 and 15 or 15 and 16) —segmentally or overall—may be heatable or coolable or thermally insulating, wherein at least one (14, 16) of the two shells (14, 15, 16) acting on a bead (2) is axially movable with respect to the base of the device, wherein both shells (14 and 15 or 15 and 16) to be sure are conveyed concentrically to one another, but are deaxiable with respect to one another such that the axial distance between the two shells fluctuates over the circumference with a circumferential site of smallest distance (amin) and an opposite circumferential site of greatest distance (amax).

25. Drum (10) that is divided into at least 2, preferably 12 segments (11), at least 1 of which—preferably all—is or are radially movable, as a device for carrying out a process in accordance with Claims 3 or 4,

characterized in that the spreading mechanisms bringing about the radial movement of the segment(s) (11) are dimensioned of sufficient thickness so that they are capable of accommodating without damage at least a radial force equal to the product 50 N/mm times the circumferential length of the segment in question.

26. Drum (10) in accordance with Claim 25, characterized in that at least 1—preferably all— of its segments (11) is or are heatable in such a manner that its or their segment surface(s) 12, which is or are provided for contacting and plastically deforming pressing on the essentially axially extending bead seating surface (7a), can reach a temperature between 100°C and 230°C, preferably between 160°C and 180°C.

27. Drum (10) in accordance with Claim 25, characterized in that at least 1—preferably all—of its segments (11) is or are coolable in such a manner that its or their segment surface(s) 12, which is or are provided for contacting and plastically deforming pressing on the essentially axially extending bead seating surface (7a), can reach a temperature of less than 100°C, preferably below 75°C.

28. Drum (10) in accordance with at least one of the Claims 25 through 27, characterized in that the segments (11) can be moved apart by different distances in the radial direction.

29. Device for carrying out a process in accordance with claim 6 or 7, characterized in that for grasping a tire bead it has two rings, at least one of which is divided into two, preferably twelve, segments, at least one of which can be moved axially.

30. Device in accordance with claim 29, characterized in that segments of two rings located axially opposite one another can be moved axially toward one another.

31. Device in accordance with claim 29 or 30, characterized in that at least one—preferably all—of its segments is or are heatable, so that its or their segment surface(s) that is or are provided for contacting and plastically deforming pressing on the essentially radially extending surfaces (7b, 7r) may reach a temperature between 100°C and 230°C, preferably between 160°C and 180°C.

32. Device in accordance with claim 29 or 31, characterized in that at least one—preferably all—of its segments is or are coolable, so that its or their segment surface(s) that is or are provided for contacting and plastically deforming pressing on the essentially radially extending surfaces (7b, 7r) may reach a temperature below 100°C, preferably below 75°C.

33. Drum in accordance with one of the Claims 25 through 28 and/or device in accordance with at least one of the claims 29 to 33 [sic], characterized in that each of its segments can be adjusted to different temperatures by independent cooling and/or heating.

34. Drum in accordance with one of the Claims 25 through 28 and/or device in accordance with one of the claims 29 to 33, characterized in that the mutually movable segments (11, 12) can be flattened at their joining sites (11.1, 12.1).

35. Process in accordance with one of the Claims 1 through 20, characterized in that the bead (2) during the plastically deforming aftertreatment is at least regionally set into vibration, preferably in the ultrasonic range.

36. Device in accordance with one of the Claims 21 to 34 for carrying out a process in accordance with claim 35, characterized in that at least one of the components of the device that touches the bead (2) during the plastic deformation is capable of making the device vibrate, or to make the bead rubber vibrate through a force acting on the bead core, in each case preferably in the ultrasonic range.

FIG. 1

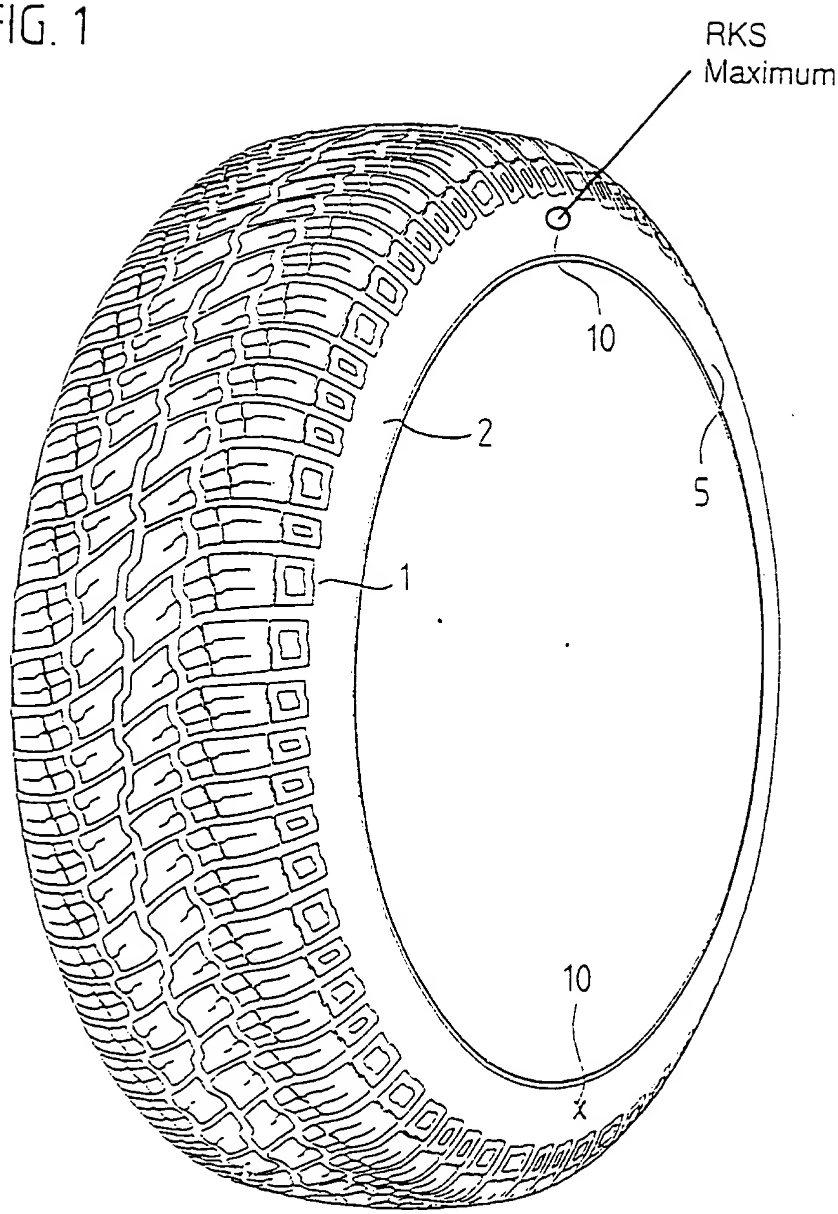


FIG. 2

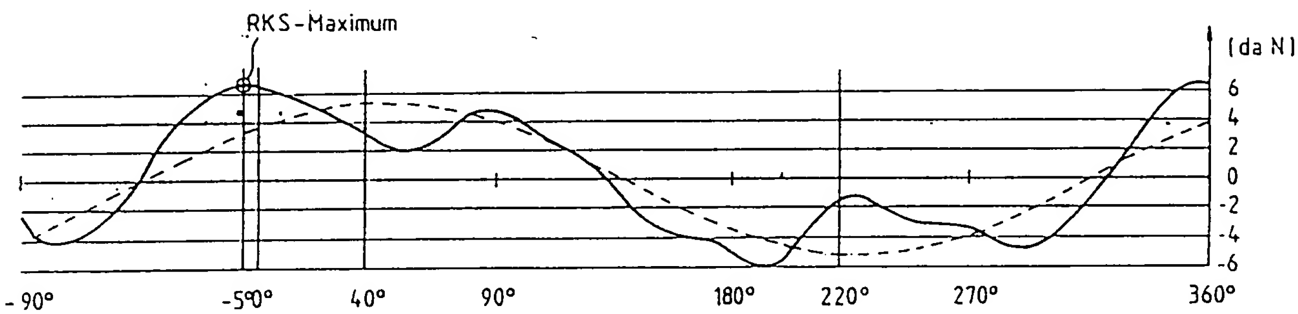


FIG. 3

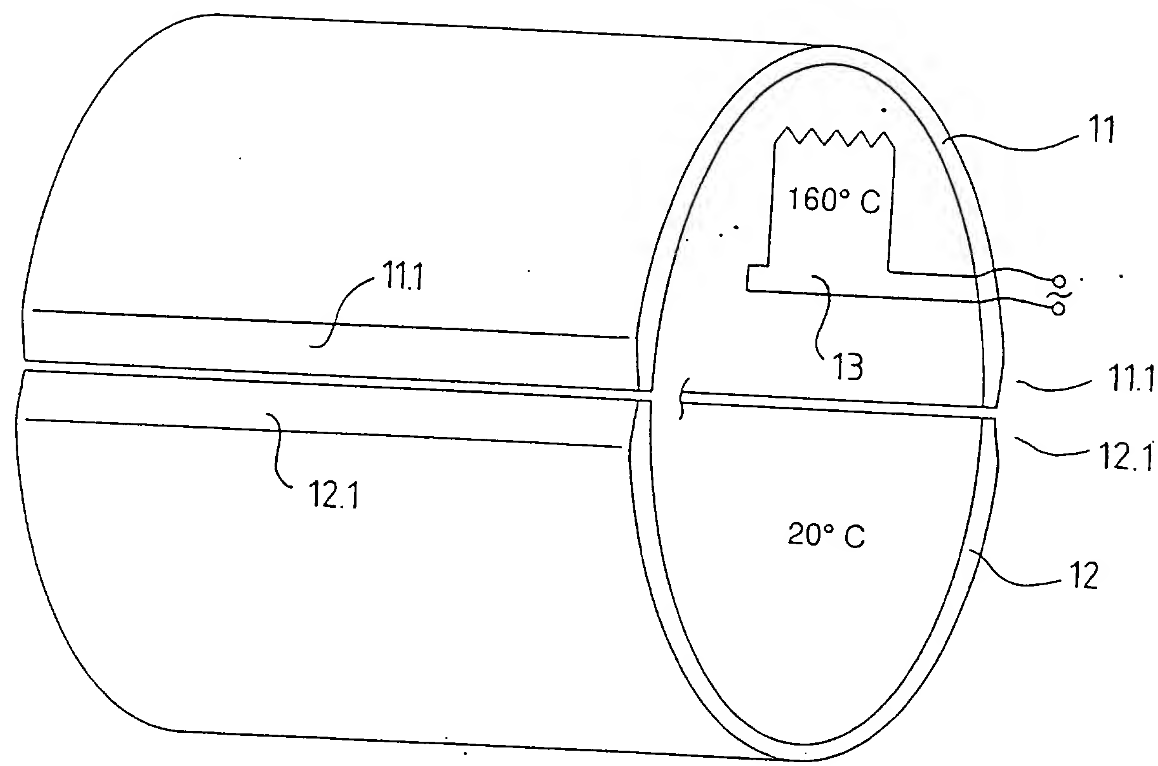


FIG. 4

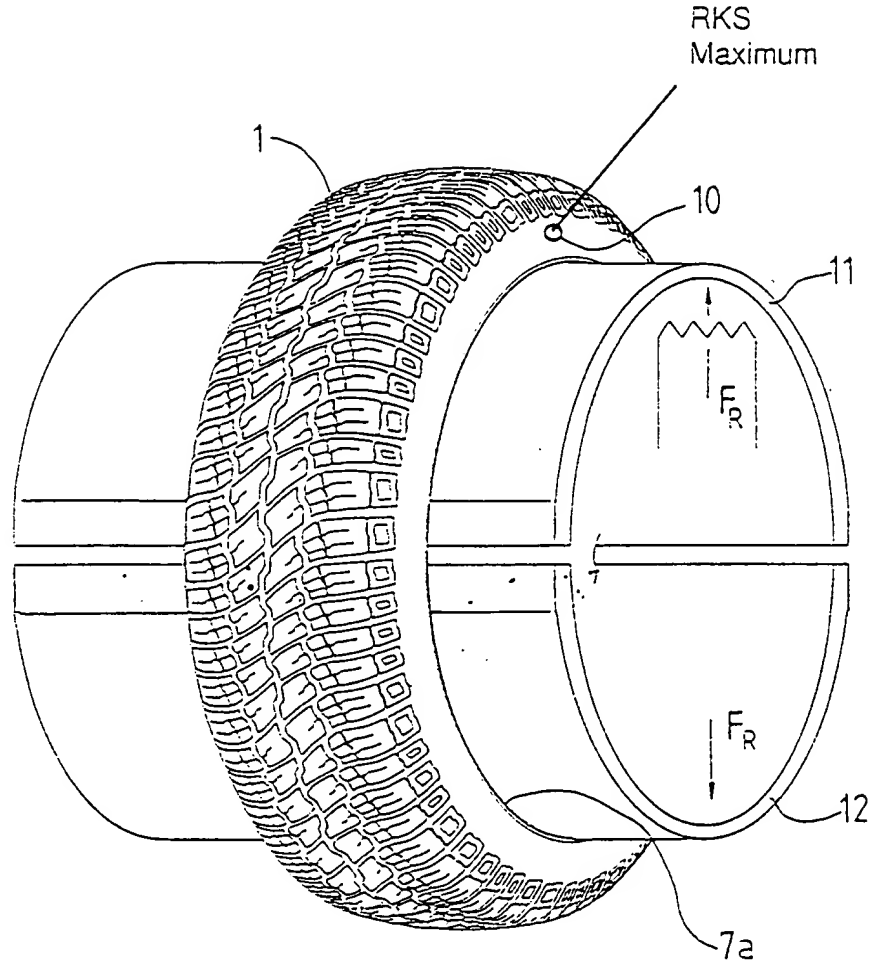


FIG. 5

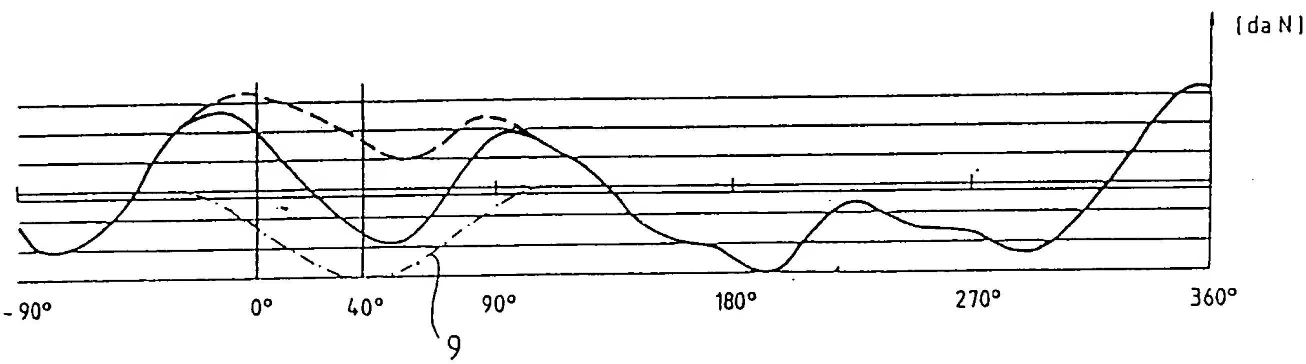


FIG. 6

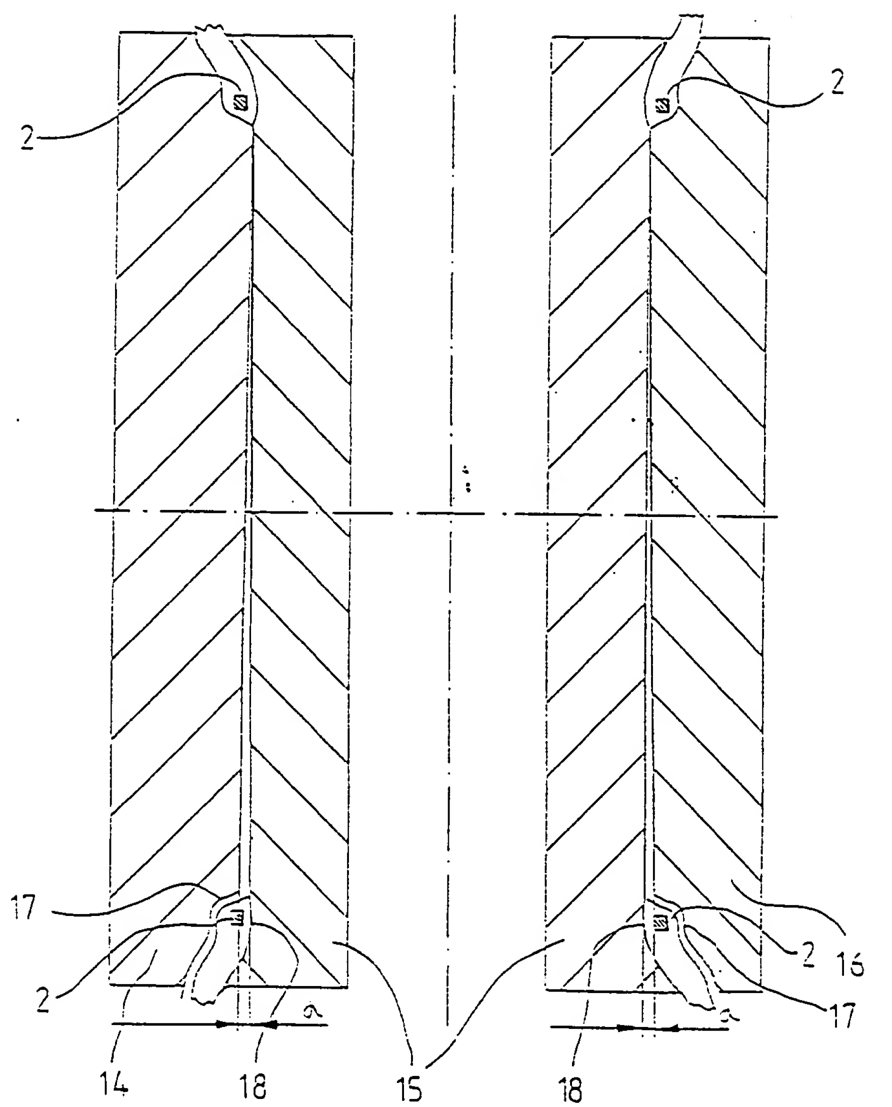


FIG. 7

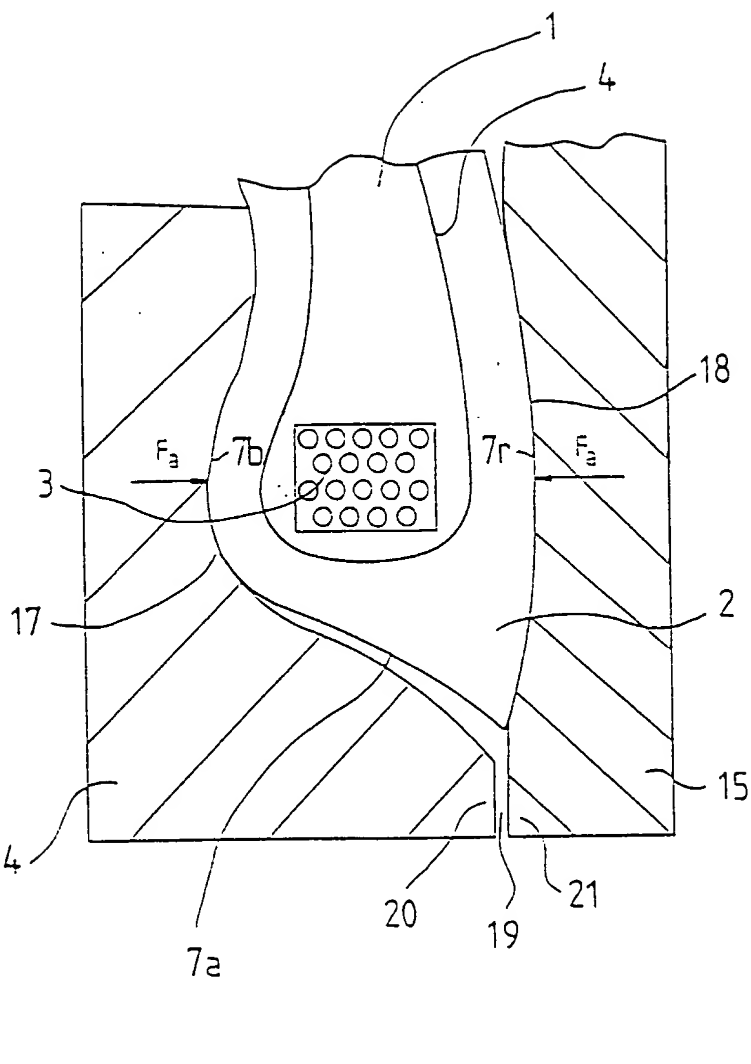
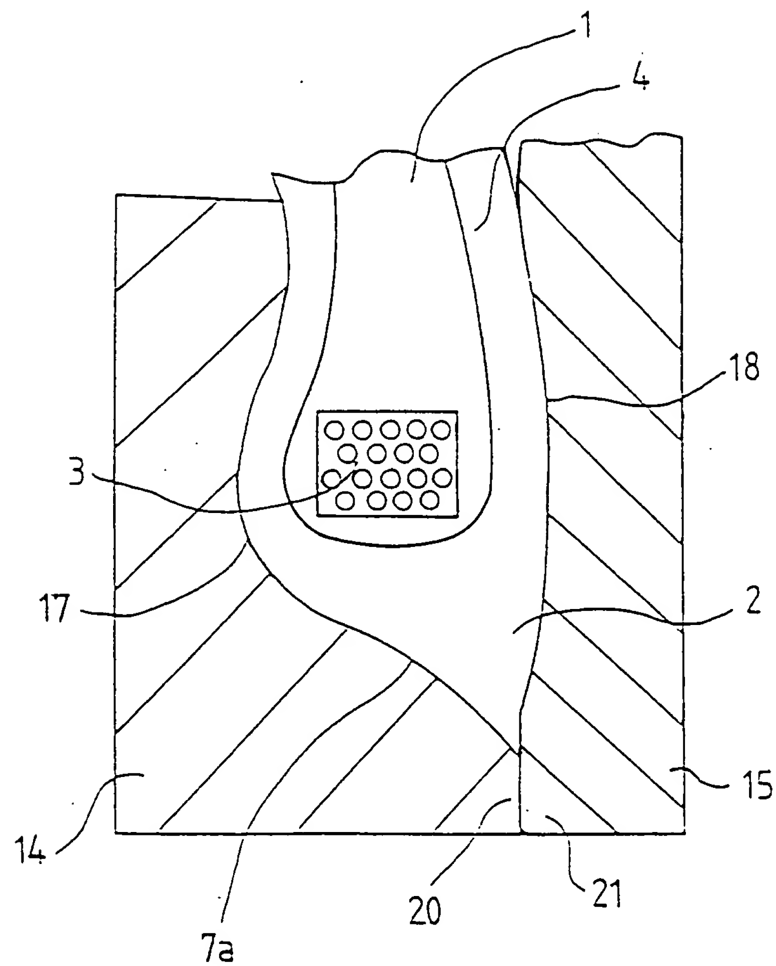


FIG. 8



INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 98/07088

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G01M1/30 G01M1/38

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G01M 3290 F16F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	DE 24 55 279 A (CONTINENTAL GUMMI WERKE AG) 12 August 1976 see page 2	1
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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
16 March 1999	23/03/1999

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Dietrich, A

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INTERNATIONAL SEARCH REPORT

International Application No
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INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 98/07088

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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INTERNATIONAL SEARCH REPORT

Information on patent family members

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